Criterion 3: Program Outcomes

1. Process for Establishing and Revising Program Outcomes

Figure 3-1 illustrates the connection between the various strategic planning components (OSU Mission, COE Mission, and CBEE Mission) and the tactically-focused objectives (PEOs) and outcomes (Program Outcomes, Performance Criteria, and Course Learning Outcomes). Because of this linkage, the focus within CBEE has been to establish robust processes for developing Course Learning Outcomes that support both course goals as well as Program Outcomes. Additionally, the Course Learning Outcomes must ultimately provide students with the experiences needed to be successful as a practicing engineer or in graduate studies.

Program Outcomes describe what students are expected to know and be able to do by the time of graduation. Program Outcomes, when combined, represent the skills, knowledge, and behaviors that students acquire in their matriculation through the BIOE program. The main constituents involved in the establishment and revision of the POs include the BIOE Program faculty in collaboration with the IAB. The development of POs was initiated in 1996 with the development of the program and its approval by the OSU Faculty Senate. The initial POs were approved by the IAB in 1999, and these were modified to conform to the ABET 2000 criteria in August 2005.

The current process by which the POs are revised may take one of two paths. First, initiation of revision may come from IAB members. For example, during the annual meeting with our IAB in Fall 2007, it was recommended that the POs be modified to reflect that graduates should possess a general knowledge of “good laboratory and clinical practices” (Program Outcome p), and an
awareness of “entrepreneurship” (Program Outcome q). Members of the IAB believed that these areas of knowledge would make important contributions towards the fulfillment of the Program Educational Objectives, specifically the objectives that relate to work-readiness (PEO 1) and ability to solve problems in a manufacturing, research or clinical environment (PEO 2). These recommendations were incorporated into the outcomes cited above, and shared with the CBEE faculty. The POs that appear in this report, which reflect these modifications, were formally adopted in March 2008.

The POs can also be revised through the initiative of the Bioengineering Program faculty, in response to the outcomes provided by the various levels of assessment and evaluation (course-level through PEOs). As described in detail in section 3.6, all Bioengineering Program faculty members are involved in the assessment and evaluation processes that periodically document and demonstrate the degree to which the Program Outcomes are attained. This process results in a final evaluative statement for each PO that provides specific recommended actions that should be pursued in order to enhance the attainment of the PO. These statements are then reviewed by the BIOE Assistant School Head, in parallel with the review of the other assessment and evaluation processes used to gauge the program’s success. Following the broad review, the BIOE Assistant School Head may recommend changes to the Program Outcomes. Any recommended changes will be reviewed by the School’s faculty and the IAB before implementation. Changes to the BIOE PEOs might, for example, require modifications to the Program Outcomes.

2. Program Outcomes

The Program Outcomes for the B.S. degree program in Bioengineering state that graduates must demonstrate that they have:

(a) an ability to apply knowledge of mathematics, science, and engineering;

(b) an ability to design and conduct experiments, as well as to analyze and interpret data;

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;

(d) an ability to function on multi-disciplinary teams;

(e) an ability to identify, formulate, and solve engineering problems;

(f) an understanding of professional and ethical responsibility;

(g) an ability to communicate effectively;
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;

(i) a recognition of the need for, and an ability to engage in life-long learning;

(j) a knowledge of contemporary issues;

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice;

(l) general knowledge of and ability to apply molecular and cellular biology, biochemistry and physiology, with extended knowledge in at least one of these areas;

(m) an ability to apply advanced mathematics, science, and engineering to solve problems at the interface of engineering and biology, including those associated with the interaction between living and nonliving materials and systems;

(n) an ability to design experiments, make measurements on and interpret data from living systems;

(o) an understanding of issues surrounding difference, power and discrimination in the engineering profession;

(p) general knowledge of regulatory issues, including pre-clinical and clinical protocols, proper documentation, and good manufacturing, laboratory, and clinical practices;

(q) an awareness of the business forces that impact design and decision making, such as entrepreneurship, financial constraints, profitability, and intellectual property and patent issues.

Note that the list includes the general ABET Program Outcomes (a-k), and six BIOE-specific Program Outcomes (l-q). Of the six program specific outcomes, three relate to areas of competency outlined within the Program Criteria for Bioengineering Programs (l-n), and three relate to additional areas of competency that directly support the BIOE PEOs, as identified by the Bioengineering Program faculty and the IAB. The BIOE Program Outcomes are documented on the web at http://cbee.oregonstate.edu/bioe/undergrad.html.

3. Relationship of Program Outcomes to Program Educational Objectives

The POs directly support the PEOs such that if all of the POs are achieved at the time of graduation, the PEOs should be realized within two to five years after graduation. That is, the skills, knowledge and behaviors identified in the POs should provide a sufficient foundation upon which graduates can aspire toward professional goals. While most of the POs support attainment of all the PEOs, for each PO one can discern to which PEO it corresponds best. A complementary mapping of this type has been developed between the Program Outcomes (a-q)
and the BIOE PEOs. This relationship is summarized in Figure 2-2. Rationale for the particular linkages will not be presented, as the placement is straight-forward and self-explanatory. Note that the assessment data for the POs will be presented and discussed in section 3.6, including discussion of how the data provides evidence of achievement along each of the PEOs.

4. Relationship of Courses to Program Outcomes

The general and specific Program Outcomes for BIOE have been further defined through the development Performance Criteria (3 or 4 per PO). Performance Criteria were created to more clearly define the knowledge, skills, and/or behaviors that students must exhibit to demonstrate achievement of a particular Program Outcome. A first draft of Performance Criteria for Program Outcomes a-k was originally created by a team of representatives from each of the programs across the College of Engineering. These Performance Criteria were further refined by the Bioengineering Program faculty. This group of faculty was also responsible for drafting Performance Criteria associated with the BIOE-specific Program Outcomes.

Within the BIOE program, some courses play a more significant role in developing the needed knowledge, skills, and behaviors expected of graduates than do others. The Bioengineering Program faculty developed a detailed assessment plan, which maps specific Course Learning Outcomes from key courses required in the BIOE program to the Performance Criteria of the POs. For each performance criterion, specific direct measures of student achievement have been identified, providing a direct measure of the degree to which the PO is met.

At the individual course level, required courses within the control of the School’s programs are evaluated, as well as the four bioengineering selection courses. The rationale for this is that not all graduates will have completed general electives, so the development of knowledge, skills, and behaviors would not necessarily be represented in all graduates. Thus, the achievement of Program Outcomes must be met within the required set of courses specified for a program, and enhanced through completion of the bioengineering selections. Within the subset of required courses, the assessment plans and evaluation process are focused on only a subset of the possible linkages between Course Learning Outcomes and the Program Outcomes (please see Table 3-1). A summary matrix of the linkages used in Program Outcome assessment is included in Appendix F. This matrix maps specific Course Learning Outcomes to Performance Criteria of Program Outcomes. In addition, the matrix also indicates the direct measures that are being recorded for evaluation of PO attainment.

5. Documentation

Materials available for the evaluation team, in addition to those provided in this report, will include among other items: annual course assessments, an assessment of and evaluative statement for each BIOE PO (based on relevant course-level assessments of student achievement along each PO), and student work samples that have been collected (based on the Performance Criteria assessment plan) and organized by Program Outcome. Each of these will be discussed below.
Table 3-1. Program Outcomes Linkage to Key Courses. “S” indicates that the course makes a substantial contribution to program outcome attainment.

### BIOE Program Learning Outcomes

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Table 3-1 (cont.). Program Outcomes Linkage to Key Courses. “S” indicates that the course makes a substantial contribution to program outcome attainment.

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Course assessment summaries

Each required course has a faculty member assigned who is responsible for instruction, as well as developing an assessment plan and collecting data to evaluate whether or not the Program Outcomes supported by specific Course Learning Outcomes (CLOs) have been met. This evaluation process is also used by faculty more generally to identify opportunities for improvement in the course. While the general format for assessment planning and evaluation are common across CBEE, faculty members are encouraged to select measures that are most appropriate to the course and to the instructor’s experience with the course.

Course assessment summaries are written each time a course is taught within CBEE, and have been maintained, in the current format, since 2003. The instructor of the course is responsible for completing the summary, which contains:

- syllabus including major topics, course learning objectives, and textbooks/reference material;
- linkage of Course Learning Outcomes to the Program Outcomes;
- description of the course plan including teaching methods used for each CLO;
- summary of assessments for students’ preparedness for the course;
- summary of three measures of achievement along each CLO; and
- narratives describing results from the last evaluation, changes made, analysis of assessment data, and recommendations for the next course offering.

Courses within the BIOE program are the major conduit through which students develop the skills, knowledge, and behaviors expected of the program’s graduates. Thus, a focus within CBEE has been to develop CLOs that support both course goals as well as Program Outcomes. The course summaries clearly identify which POs the course supports, proving a linkage between each CLO and the supported PO(s). Three distinct measures of competency relevant to each CLO (two direct and one indirect) are obtained. The indirect measure of CLO Achievement is recorded through a standardized end of term course survey that is administered by CBEE administrative staff. The survey data are recorded during week 9 or week 10 of the term. The summarized data are then provided to instructors at the beginning of the following term (following the assignment of course grades). In addition to this indirect measure, faculty must also identify two other direct measures to evaluate the achievement of CLOs and ultimately of the linked Program Outcome. Specific assignments, exams, project reports, and grading rubrics are used by faculty for direct measures as appropriate to a given course, Course Learning Outcome, and linked Program Outcome. Course assessment summaries from the past three years will be made available, as the program was last reviewed during the 2005-2006 academic year.

Assessment of and evaluative statements for Program Outcomes

On a biannual basis, a course-level assessment of achievement along each of the POs supported by a given course (see Table 3-1 for linkages between key courses and the Program Outcomes) is completed by the assigned instructor. This assessment begins by noting which CLOs correspond to a particular Program Outcome. This data is part of the course assessment summary (described above). This linkage is further refined in that each CLO is identified as supporting one of the 3 or 4 Performance Criteria of the noted PO. Sometimes, a given CLO is mapped to two Performance Criteria of a given PO, but that is an exception (not because a given CLO would not support multiple criteria, but because this increases work volume). Once mapped to a given Performance Criterion, measures of competency relevant to the CLO are
noted, and a narrative is written that describes the activities involved in the measures and how they relate to the linked Performance Criterion. Finally, an overall summary statement describing achievement along each of the POs supported by the course is drafted.

Following completion of the course-level assessments described above, a program-level evaluation of achievement for each PO is conducted. An evaluation of a given PO provides the summaries of achievement from each of the key courses (described above) supporting the outcome, and provides an evaluative statement regarding achievement of each related Performance Criterion. The statement also indicates whether or not action is required to remediate any noted deficiencies in achievement. The Bioengineering Program faculty are responsible for completing the program-level evaluation; the four faculty members divide the outcomes in accordance to their interests and expertise.

The 2005-06 and 2006-07 summary statements for each PO, at both a course- and program-level, will be available for the evaluation team. As described below, assessment of the POs across the curriculum will take place biannually, so a 2007-08 assessment and evaluation did not occur.

**Student work samples**
Student work samples from 2007-08 will be made available to the review team in an electronic format. In particular, direct measures of competency relevant to the Performance Criteria of each Program Outcome have been recorded. At least three samples of work were collected for each measure, demonstrating different levels of competency. These samples will be organized according to Program Outcome, sub-divided by Performance Criteria.

### 6. Achievement of Program Outcomes

The following section describes the assessment and evaluation process used to demonstrate the degree to which the POs are attained, and also provides a summary of achievement level attained for each PO based on data recorded since our last ABET review.

**Assessment and evaluation process**
Our assessment strategy includes direct measures of competency along each program outcome, through course- and program-level assessment and evaluation. In addition, surveys administered to exiting seniors, alumni, and employers of our graduates provide indirect measures of the degree to which each of the POs are attained. These assessment methods are described below.

*Input from course- and program-level assessment and evaluation*
On a biannual basis, a course- and program-level assessment of achievement along each of the POs is conducted. The processes by which this is completed is described in detail above (please see section 3-5). New faculty members are trained on these processes by the BIOE Assistant School Head.

*Input from graduating seniors*
Since 2002, graduating seniors have been required to critically evaluate their level of competency along each of the program outcomes a-q. For each outcome, they quantify their level of competency using a 5-level Likert scale. They also write a thorough self-assessment
statement for each, which is basically a personal reflection of achievement. This data is recorded annually as part of the senior capstone design course. The instructor of the design course is responsible for calculating average competency levels for each PO, as well as summarizing associated comments, especially those comments that appear in multiple student evaluations. The data from this measure will be presented and discussed below.

Graduating seniors are also asked to complete a web-based survey during the final weeks of their programs. Among other topics, they are asked to reflect on their ability to meet each of the POs, using a 5-level Likert scale. While not shown here, results from the exit surveys will be made available to the evaluation team. A copy of the Exiting Senior Survey is included in Appendix E.

Input from alumni
Web-based surveys are administered yearly to cohorts of students that are 3 years post graduation. Among other topics, alumni are asked to reflect on their ability to meet each of the POs, using a 5-level Likert scale. A copy of the Alumni Survey is included in Appendix E.

Input from employers of our graduates
A relatively large number of BIOE graduates pursue advanced degrees or enroll in professional school. As noted above, we have identified the employers of our graduates and graduate schools that enroll our graduates among the most immediate constituencies of our program. Thus, we sought input from both of these groups regarding our graduates’ educational preparedness. Specifically, representative employers of or academic advisors of students who are 3 years post graduation are asked to respond to a web-based survey. Among other topics, employers are asked to reflect on their employee’s or advisee’s ability to meet each of the POs, using a 5-level Likert scale. A copy of the Employer Survey is included in Appendix E.

Evaluation of achievement
The BIOE Assistant School Head is responsible for ensuring all assessment data is recorded annually, and for analyzing the data on a biannual basis. The focus of this analysis is to identify changes and/or trends in the data set for the achievement of PEOs, and link the trends back to program outcomes data and curricular-level initiatives or gaps. Program strengths and weaknesses, identified as a result of this bi-annual evaluation, are presented to the CBEE faculty as well as shared with the IAB. The BIOE Program faculty, in collaboration with the CBEE Undergraduate Program Committee is then responsible for identifying program, curriculum, and/or course-level improvements as indicated by the evaluation.

Achievement of POs
Analysis of the direct and indirect measures of PO achievement is completed by the BIOE Assistant School Head. The 2006-2008 biennium data for each measure is presented below, followed by a discussion of how it provides evidence of achievement along each of the PEOs.

Evaluation of PO achievement: course- and program-level assessment
The course- and program-level evaluations of achievement along each PO are completed by CBEE faculty. These direct measures of achievement demonstrate that each PO is adequately met. That is, course-level assessments show the averaged scores of student work supporting the Performance Criteria for each PO to be above 70%. Program-level evaluations of achievement
along each PO provide the summary statements from the course-level assessments and an evaluation of achievement across the program for the Performance Criteria associated with each PO. Figure 3-2 is an example program-level evaluation of achievement for Program Outcome “i.” Note that student achievement along this outcome was measured in four courses. While the assessments show that achievement along each of the POs is adequate, these processes also produce a list of areas that could be improved in order to enhance student learning. These will be discussed in detail in section 4.2 of this report. All course- and program-level assessments and evaluations will be available to the evaluation team, along with associated student work.

**Evaluation of PO achievement: Graduating seniors**

Figure 3-3 displays the self-assessment of competency along each PO for graduating seniors over the last three academic years. To help place the graduate self-ratings of achievement in context, data recorded in the Employer Survey was used to establish the importance of each of the Program Outcomes to success in the workplace. Gaps between student achievement and importance to success help identify areas where improvements can be made. Employers rated each of the POs’ importance to be between 4.0-4.8; thus, we deemed achievement scores above 4.0 on the 5-level Likert scale as adequate achievement. Using this basis, according to the graduates, the BIOE program is very successful in preparing students to achieve the POs, with the exception of PO “q” (awareness of business forces that impact design and decision making). The greatest opportunity for improvement of the BIOE program is in this area. Data for outcomes “c” and “j” also fall below the 4.0 cut-off, depending on the year in which the students graduated. Actions taken to remediate these deficiencies will be discussed in section 4.2 of this report. Note that all survey data recorded will be available to the evaluation team. The self-assessments completed by graduating seniors will be available as well. We have these assessments for each graduating class since the last ABET review.

**Evaluation of PO achievement: Alumni**

Figure 3-4 displays the self-assessment of competency along each PO for alumni who graduated between 2003 and 2005. The alumni also rated the importance of each PO to workplace success, and this data is represented on the plot as well. Gaps between achievement and importance to success help identify areas where improvements can be made. In general, alumni rated each of the POs’ importance to be above 4.0; as above, we deemed achievement scores above 4.0 on the 5-level Likert scale as adequate achievement. Using this basis, according to the alumni, the BIOE program is very successful in preparing students to achieve most of the POs, but the data shows deficiencies in the areas of design (“c”), solving engineering problems (“e”), use of engineering tools (“k”), and awareness of business forces (“q”). Several of these deficiencies have already been addressed during the 3-5 year period since the respondents’ graduation. These actions, as well as planned actions to be taken to remediate noted deficiencies will be discussed in section 4.2 of this report. Note that all survey data recorded will be available to the evaluation team.

**Evaluation of PEO achievement: Employers and advisors of our alumni**

Figure 3-5 displays the level achievement displayed by our graduates 3-5 years post-graduation, as rated by their employers (or academic advisors). The employers also rated the importance of
Program outcome (i): a recognition of the need for, and an ability to engage in life-long learning

Academic year 2006-2007
Assessment filed by Michelle Bothwell

Summaries from courses in which this outcome was assessed:

**BIOE 220 Professionalism and Bioengineering Ethics**
This course specifically deals with the need for life-long learning in order to meet one’s responsibilities as an engineer. However, none of the performance criteria that describe this program learning outcome are really appropriate for the type of learning that is engaged here. I placed the assessment under the third criterion because students are taught to determine the limits of their knowledge so that they may only engage projects within their competency. In any event, this course provides a sound justification for continued learning, and most students completing the course have placed life-long learning into their developing professional schema.

**BIOE 414 Process Engineering Laboratory**
As part of the required activities in this course, (data analysis and interpretation in Unit Operations assignments, report and white paper writing), students must locate information in specific references (e.g., Perry’s Chemical Engineer’s Handbook, CRC Handbook, etc) or search the current literature to identify literature information (using SciFinder, Compendex, Inspec and the Science Citation Index) germane to the process under analysis.

**BIOE 470 Regulation of Drugs and Medical Devices**
This course speaks directly to the need for life-long learning in order to meet one’s responsibilities as an engineer in the modern bioscience-based industries. However, the performance criteria do not “mesh” plainly with the CLOs and assigned activities. Students certainly took advantage of learning opportunities by attending professional guest lectures from representatives from FDA, industry and consulting firms, but none of this was outside of formal class activities (as specified in the first performance criteria below). In the context of cGMP, I certainly believe they demonstrated the ability to secure additional knowledge and the deeper understanding required to carry out a design or related activity. And in the same context, I believe they showed they understand there are no “standard” documentation protocols, that multiple interpretations of cGMP exist, etc., and can identify specific resources available to help them deal with such challenges.

**BIOE 490 Bioengineering Design**
In the self evaluation, the students reflect in writing on their performance on each program outcome, in addition to their performance the students discuss what activities they engaged in to develop the outcome – this includes outcome i. These activities invariably include learning opportunities outside of formal class activities (professional lectures, seminars, short courses, internships, etc.). For the project, the students must secure additional knowledge about their specific processes by reading the technical literature, and acquire a deeper understanding to carry out a their capstone design. They must use theory in combination with physical practicalities in selecting and sizing equipment. Action: In the peer assessment the students are not required to indicate outside activities that contributed to their performance on outcomes other than i, next year this will be in the assignment language.
Assessment of Performance Criteria Associated with Outcome (i)

1. Takes advantage of learning opportunities outside of formal class activities by attending professional lectures, seminars, short courses, etc.
   All of our students attend professional guest lectures from representatives from FDA, industry and consulting firms, as part of formal courses. Guests are invited in order to bring current issues into the classroom, including topics related to new technology development, and new issues related to intellectual property and patents and regulatory procedures, among others. A significant number of our students engage in learning opportunities beyond the classroom, however this activity is harder to document. In BIOE 490, students are required to compose a self assessment journal speaking directly to each program outcome. They indicate how well they believe they achieve each outcome and provide examples from their experiences. For outcome ‘i’ many examples of competency involve participation in internships, MECOP, and professional club activities, in addition to attending seminars and engaging in international study.
   Action: Further investigation warranted. Improve documentation of participation in professional activities that take place outside of a formal class setting. This could be incorporated in the design course’s “self assessment journal.”

2. Demonstrates ability to secure additional knowledge and deeper understanding required to carry out a capstone design or lab activity.
   As part of the required activities in several courses (in BIOE 414 and BIOE 490 in particular), students must secure additional knowledge about specific processes, and acquire a deeper understanding of them to carry out their laboratory or capstone design. Students are successful at locating information in specific references (e.g., Perry’s Chemical Engineer’s Handbook, CRC Handbook, etc) and at searching the current literature (using SciFinder, Compendex, Inspec and the Science Citation Index) to identify information germane to the process under analysis. They demonstrate understanding of the dynamic nature of cGMP as well, and are able to secure the additional knowledge needed to carry out a design or related activity.
   Action: No action required at this time.

3. Analyzes limits to theory/approximations used in a specific class when applied to real-world engineering problems, and identifies specific technical resources available to bridge the gap.
   Through completing activities in the professionalism course, students recognize the role of life long learning in meeting one’s responsibilities as an engineer. Students know they must determine the limits of their knowledge so that they only engage projects within their competency, and most leave the course having placed life-long learning into their developing professional schema. Given this foundation, students are provided opportunities to evaluate limits of knowledge, including limits associated with applications of theory/approximations, and to identify resources to address these concerns. In particular, during senior design, they must use theory in combination with physical practicalities in selecting and sizing equipment, and in senior lab they must identify information germane to the process under analysis through literature searches in order to complete protocols. Finally, students understand there are no “standard” documentation protocols, that multiple interpretations of cGMP exist, etc., and can identify specific resources available to help them deal with such challenges.
   Action: Further investigation warranted. Students could be provided more opportunities to practice evaluating limits in theories/approximation and knowledge, and to identify paths to resolution. Perhaps the team-based project in the biomedical engineering principles course, which involves proposal and design of experiments, could incorporate something along these lines.
Figure 3-3. Exiting senior evaluation of PO achievement compared to employer importance ratings.

(a) apply mathematics, science and engineering
(b) design & conduct experiments, analyze & interpret data
(c) design a system, component or process
(d) function on multi-disciplinary teams
(e) identify, formulate and solve engineering problems
(f) understand professional and ethical responsibility
(g) communicate effectively
(h) understand engr solutions in global, economic, environmental & societal context
(i) recognize the need for engagement in lifelong learning
(j) knowledge of contemporary issues
(k) use techniques, skills and modern engineering tools
(l) knowledge of and application of mol & cell biology, biochem and physiol
(m) apply math, science and engr to solve problems at interface of engr & bio
(n) design experiments, make measurements on & interpret data from living systems
(o) understand links between DPD and engineering profession
(p) knowledge of regulatory issues
(q) awareness of business forces that impact design & decision making
Figure 3.4. Alumni evaluation of PO achievement compared to alumni importance ratings.

Achievement Level
(1-low achievement, 5-high achievement)

Importance in the Workplace
(1-not important, 5-very important)

(a) apply mathematics, science and engineering
(b) design & conduct experiments, analyze & interpret data
(c) design a system, component or process
(d) function on multi-disciplinary teams
(e) identify, formulate and solve engineering problems
(f) understand professional and ethical responsibility
(g) communicate effectively
(h) understand engr solutions in global, economic, environmental & societal context
(i) recognize the need for engagement in lifelong learning
(j) knowledge of contemporary issues
(k) use techniques, skills and modern engineering tools
(l) knowledge of and application of mol & cell biology, biochem and physiol
(m) apply math, science and engr to solve problems at interface of engr & bio
(n) design experiments, make measurements on & interpret data from living systems
(o) understand links between DPD and engineering profession
(p) knowledge of regulatory issues
(q) awareness of business forces that impact design & decision making
Figure 3-5. Employer evaluation of Alumni’s PO achievement compared to employer importance ratings.

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<th>PO Achievement</th>
<th>Importance in the Workplace</th>
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<tbody>
<tr>
<td>(a) apply mathematics, science and engineering</td>
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<tr>
<td>(b) design &amp; conduct experiments, analyze &amp; interpret data</td>
<td>4</td>
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<tr>
<td>(c) design a system, component or process</td>
<td>5</td>
</tr>
<tr>
<td>(d) function on multi-disciplinary teams</td>
<td>5</td>
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<tr>
<td>(e) identify, formulate and solve engineering problems</td>
<td>5</td>
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<tr>
<td>(f) understand professional and ethical responsibility</td>
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<td>(g) communicate effectively</td>
<td>5</td>
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<tr>
<td>(h) understand engr solutions in global, economic, environmental &amp; societal context</td>
<td>4</td>
</tr>
<tr>
<td>(i) recognize the need for engagement in lifelong learning</td>
<td>5</td>
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<tr>
<td>(j) knowledge of contemporary issues</td>
<td>4</td>
</tr>
<tr>
<td>(k) use techniques, skills and modern engineering tools</td>
<td>5</td>
</tr>
<tr>
<td>(l) knowledge of and application of mol &amp; cell biology, biochem and physiol</td>
<td>4</td>
</tr>
<tr>
<td>(m) apply math, science and engr to solve problems at interace of engr &amp; bio</td>
<td>5</td>
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<tr>
<td>(n) design experiments, make measurements on &amp; interpret data from living systems</td>
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<tr>
<td>(o) understand links between DPD and engineering profession</td>
<td>4</td>
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<tr>
<td>(p) knowledge of regulatory issues</td>
<td>4</td>
</tr>
<tr>
<td>(q) awareness of business forces that impact design &amp; decision making</td>
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each PO to workplace success, and this data is represented on the plot as well. Gaps between alumni achievement and importance to success help identify areas where improvements can be made. Employers rated each of the POs’ importance to be between 4.0-4.8; again, we deemed achievement scores above 4.0 on the 5 –level Likert scale as adequate achievement. Note that there is no data for PO “n” (experimentation involving living systems). The questions referring to this PO were inadvertently left off the survey.

According to the employers of our graduates, the BIOE program is very successful in preparing students to achieve most of the POs, but the data shows deficiencies in the areas of bioscience knowledge (“l”), regulatory knowledge (“p”), and awareness of business forces (“q”). A couple of these deficiencies have already been addressed during the 3-5 year period since the alumni’s graduation. These actions, as well as planned actions to be taken to remediate noted deficiencies will be discussed in section 4 of the report. Note that all survey data recorded will be available to the evaluation team.

*Connection to the achievement of PEOs*

As discussed in section 2.6 of this report, survey data recorded to assess achievement of the PEOs (from exiting seniors, alumni, and employers of alumni) demonstrate adequate attainment, if one uses the same 4.0 cut-off that was used for the POs. PEO achievement ranked the lowest by alumni and employers include graduates work-readiness (average score of 4.0 and 4.1, respectively), and graduates ability to be successful in solving problems at the interface of engineering and biology, whether in a manufacturing, research, or clinical environment (average score of 4.2 and 4.3, respectively). The deficiencies noted in PO attainment correlate well with the opportunities for improvement for PEO achievement. In particular, 5 of the 6 POs identified by alumni or employers as not being adequately met correspond to skills and knowledge needed to prepare graduates to be work-ready (PEO 1). Achievement of this Program Objective was ranked lowest out of the five. Employers also noted that graduates’ knowledge of biosciences could be improved. This directly correlates with achievement in solving problems at the interface of engineering and biology (PEO 2), the second lowest ranked PEO with regards to achievement. According to all of our data, students’ acquisition of knowledge, skills and behaviors needed to successfully meet the other three BIOE PEOs (PEO 3-5) are in place.
Criterion 4: Continuous Improvement

1. Information Used for Program Improvement

The information for program improvement comes directly through the evaluation processes that have been described in Criteria 2 and 3. Overall, a plan, do, study, act (PDSA) cycle has been used as the foundation for the continuous improvement process developed within the school of CBEE as illustrated in Figure 4-1. W.A. Shewhart was the first to introduce this model, often used for continuous quality improvement. It contains 4 steps: develop a plan for improving quality of a process (plan); execute the plan (do); evaluate data or feedback (study); and identify what changes should be made before the next cycle (act). The data used for this improvement cycle include individual course assessments, survey data from exiting seniors, alumni and employers of our alumni, comments from the exiting senior interviews, data from the advising survey, as well as course- and program-level evaluation data for PO attainment (connecting direct measures from student work to PO achievement). The BIOE Assistant School Head summarizes results from the program-level evaluations of the POs, organizing needed actions into the categories of “immediate action required” and “further investigation warranted.” If a particular PO did not require attention, as determined through the program-level evaluation, it is not listed on the summary. Summaries of actions required for enhancing achievement of POs for AY 2005-2006 and AY 2006-2007 are in Appendix G. These lists are important guides to formulating improvement strategies. Ideas for program improvement also arise through meetings with stakeholders, particularly members of the IAB, as well as from the informal benchmarking of other programs, e.g., through conversations with colleagues in other programs and through attendance at national meetings. Recommendations for modifications to the program may result in a program procedural change, in changes supporting infrastructure (facility enhancement, purchasing of new software or instructional equipment, hiring of additional TAs or instructors, etc.), or in a curricular change.

![Figure 4-1. PDSA cycle for Continuous Improvement of the BIOE Program](image)

A formal procedure for curriculum change has been established. These guidelines, as they relate to course-level changes, serve as a system of checks and balances to ensure that changes made at the course-level result in a better overall program. A copy of these guidelines is provided in Appendix H. The procedure clearly defines what changes come within the scope of
responsibility of the instructor, of the CBEE Undergraduate Program Committee, or of the faculty as a whole. Note that some course- and program-level changes require a proposal submission to the University’s on-line curriculum change system for institutional review. Illustrative examples of program changes that have taken place since the last general ABET review are discussed in section 4.2, below.

2. Actions to Improve the Program

The assessment and evaluation processes described above have resulted in a number of significant program changes since the accreditation visit in 2006. Actions taken to improve the program can be categorized into three areas: procedural changes, changes to supporting infrastructure, and curricular changes. The most significant changes are described below. For each change discussed, the assessment tools from which the need for change was determined are identified, along with an indication of why the action was taken. Any specific objectives or outcomes of the program that are expected to be affected by the change are noted, as well as when each action was implemented and the results of the implementation. Many changes within courses, such as topics covered, textbooks used, and laboratories completed, have taken place as a result of the assessment processes and the feedback mechanisms in place. All minor changes to individual courses are documented in the associated course summaries; only the major changes of this type are presented below.

Procedural changes
Six significant procedural changes have occurred since the last review, and each is discussed below.

Senior self-assessment assignment. Each year, graduating seniors are required, as part of formal coursework, to complete a self-assessment relevant to their abilities to meet each of the Program Outcomes. In Spring 2006, graduating seniors were asked to also reflect on their abilities to meet each of the Program Educational Objectives.

- Assessment source leading to and rationale behind the change.
  Feedback from our last ABET visit highlighted a deficiency in the process used to evaluate the extent to which the program educational objectives are attained. The action taken was in response to this feedback, with the hope that it would provide more data that could be used in evaluation of achievement.

- PEOs and POs impacted, and results of implementing the change.
  This change impacted all PEOs. While educational objectives are linked to competencies and accomplishments expected for those two to five years post graduation, having new graduates reflect on the PEOs and their associated competencies provides them with a vision of where their career accomplishments ought to head. Also, if exiting seniors engage reflection along the PEOs, they should be better prepared to reflect upon their abilities relevant to each PEO when approached for feedback about our program 3 years post-graduation. Because this process was initiated recently, alumni who completed surveys did not engage this activity while at OSU. Thus, it is impossible to know if the change has had any impact.
Employer surveys. In Spring 2008, representative employers or academic advisors of students 3 to 5 years post graduation were asked to respond to a web-based survey. Among other topics, employers were asked to reflect on their employee’s or advisee’s ability to meet each of the Program’s educational objectives, using a 5-level Likert scale. This survey will be administered on an annual basis, to employers (or advisors) of our alumni who are 3-years post graduation.

- Assessment source leading to and rationale behind the change.
  Feedback from our last ABET visit highlighted a deficiency in the process used to evaluate the extent to which the program educational objectives are attained. The action taken was in response to this feedback, with the hope that it would provide more data that could be used in evaluation of achievement.

- PEOs and POs impacted, and results of implementing the change.
  This change impacted all PEOs. Data recorded through the employer survey was an important enhancement to our ability to effectively evaluate the extent to which our alumni were successful in meeting each of the PEOs.

Course- and program-level assessment and evaluation. In AY 2005-06, the School’s leadership team (School Head and Assistant Heads) revised the course summaries such that direct measures of PO achievement could be secured. While instructors identified direct measures of achievement for CLOs they believed most supported linked POs, the overall resulting data set was not thorough. For example, achievement of PO “i” was only assessed in one course (see Figure 4-2). Other POs did not receive adequate attention in regard to formal assessment of achievement. The summary of actions required to enhance achievement of the Program Outcomes resulting from our initial course- and program-level assessment and evaluation processes (Appendix G) identifies 7 of the 17 Program Outcomes as needing a more comprehensive, formal assessment strategy to evaluate student competencies. As a result of this feedback, in AY 2006-07, the Bioengineering Program faculty discussed which set of courses should be used in the assessment and evaluation processes, and generated a map linking each Program Outcome to a set of key courses that make a substantial contribution to the Program Outcome’s attainment (Table 3-1). During the same year, the general and specific Program Outcomes for BIOE were further defined through the development of Performance Criteria (3 or 4 per Program Outcome). Performance Criteria were created to more clearly define the knowledge, skills, and/or behaviors that students must exhibit to demonstrate achievement of a particular Program Outcome. A table of all Program Outcomes and their associated Performance Criteria can be found in Appendix I. The resulting course- and program-level assessment and evaluation, conducted at the end of AY 2006-07, was much more comprehensive then the assessment conducted in AY 2005-06. As illustrated in Figure 4-2, the previous evaluation along Program Outcome “i” (AY 2005-06) was limited to a single class, and did not consider performance criteria. For comparison, refer to Figure 3-2, the AY 2006-07 program-level evaluation of achievement for Program Outcome “i.” Note that student achievement along this outcome was measured in four courses, across three Performance Criteria. It was determined that
Program outcome (i): a recognition of the need for, and an ability to engage in life-long learning

Academic year 2005-2006
Assessment filed by Michelle Bothwell

This outcome was assessed in the following course:

BIOE 220 Professionalism and Bioengineering Ethics

The course on professionalism specifically deals with the need for life long learning in order to meet one’s responsibilities as an engineer. Students are aware that they must determine the limits of their knowledge so that they only engage projects within their competency, and that they must continually learn new knowledge and skills in order to be valued engineers, given that the sciences and technologies are continually advancing. Upon completing the course, students can provide a sound justification for continued learning, and they have placed life-long learning into their developing professional schemas. While this program outcome is addressed in other courses within the curriculum, other assessments of student learning were not completed.

Action: Identify which courses in the curriculum present material relevant to this outcome and put assessment measures of student learning in place. It is hard to know whether our students meet this outcome without a more comprehensive, formal assessment of their competency in this area.

Figure 4-2. Program-level evaluation of Program Outcome “i” for academic year 2005-06

These course- and program-level assessment and evaluation processes will be conducted on a biannual basis. The rationale is that changes made to the program based on such an evaluation would require more than one academic year to produce measurable results in PO achievement.

- Assessment source leading to and rationale behind the change.
  The need to institute a more formal method of measuring student achievement along each PO was communicated to us during our last ABET visit. It became clear that our primary focus on measuring student achievement along Course Learning Outcomes was not sufficient in regard to documenting achievement along the objectives and outcomes of the program. Actions taken were in response to this feedback, with the hope that it would provide more relevant data that could be used in evaluation of PO achievement. Feedback from our initial efforts promoted process refinement.

- PEOs and POs impacted, and results of implementing the change.
  This change impacted all POs. As discussed above, the POs are linked to the PEOs (Figure 2-2), and assessing competencies for each program outcome provides additional insight into the achievement of the PEO to which it is linked. Thus, all PEOs are affected by this change as well. Improvements in the processes used to measure the extent to which our students
meet the POs is a huge improvement in our ability to make strategic program changes that will ultimately lead to enhanced attainment of the Program Objectives.

Comprehensive advising survey. We expanded assessment of our advising program during the 2005-06 academic year to include all students in the bioengineering program, not just graduating seniors. The new assessment protocol involves students completing an in-depth survey that includes questions about the helpfulness of our advising guide, the office staff, students’ assigned advisors, and the Head Advisor. This survey also asks students to reflect on the process by which they schedule advising appointments, asks about reasons students seek advice, and whether OSU’s non-discrimination policy is upheld throughout the advising process, among other issues.

- Assessment source leading to and rationale behind the change.
  When compiling the ABET self-study report in 2005, we noticed that we did not have a lot of data about the effectiveness of our advising system. The action taken was in response to this, with the hope that administering a comprehensive survey every three years would provide adequate feedback for program improvement. A three year assessment cycle was chosen to ensure all students had the opportunity to provide feedback at least once, and to minimize the number of surveys we ask students to complete.

- PEOs and POs impacted, and results of implementing the change.
  Academic advising and career counseling have a significant impact on a student’s academic success and subsequent career trajectory, and professional development. In this way, albeit indirect, all PEOs and POs are impacted by this new assessment mechanism. Data recorded through the advising survey administered during the 2005-06 academic year have proven to be valuable, resulting in several program changes (discussed further below).

Assignment of academic advisors. Starting in fall 2008, all bioengineering students will be assigned one of the Bioengineering Program faculty as his or her academic advisor, and this pairing will remain in place throughout the student’s tenure in the bioengineering program. In the past, students in their first year of study were advised by Dr. Skip Rochefort, the instructor of the first orientation course. First- and second-term transfer students, as well as those on academic probation, were advised by the Head Advisor. While these advising relationships will remain intact, students falling into these categories will also meet with one of the Bioengineering Program faculty.

- Assessment source leading to and rationale behind the change.
  Respondents to the 2005-06 Advising Survey, as well as participants in the 2007-08 senior exit interview, expressed dissatisfaction with their advisor assignment. In particular, some indicated that it would have been nice to have one of the Bioengineering Program faculty as an advisor during their first year, and several indicated that they wished that they had been able to stay with one advisor throughout their tenure, instead of being “shuffled around” to multiple advisors. While it is current procedure to assign an academic advisor to a student for the duration of his or her tenure, the system is not working as intended. It does make a lot of sense that a student be assigned an advisor familiar with the bioengineering program, and the
bioengineering field in general, early in his or her program, and that this relationship stay intact so that continuity, familiarity and trust between the two individuals can develop.

- PEOs and POs impacted, and results of implementing the change.
  Academic advising and career counseling have a significant impact on a student’s academic success and subsequent career trajectory, and professional development. In this way, albeit indirect, all PEOs and POs are impacted by this new assessment mechanism. Because this change will not be put into practice until next fall, we do not have results to report.

*Creation of tracking forms for program changes.* Tracking forms that formally document program changes have been created. They include a description of the action taken, the date the change was implemented, and the basis for the change, among other items (Appendix J includes an example form). Use of these forms will be formally implemented in Fall 2008.

- Assessment source leading to and rationale behind the change.
  When compiling the ABET self-study report this spring, informal benchmarking with other programs that had undergone recent review led to creation of this documentation method. Prior to this time, we did not have a formalized means to track program changes, making the task of generating a list of changes that occurred over a period of time (as we are doing here) rely heavily on faculty memory, and notes from, e.g., faculty meetings, committee meetings and IAB meetings.

- PEOs and POs impacted, and results of implementing the change.
  This change in procedure will not directly impact student achievement along any PEO or PO, but will make the process of continuous program improvement more transparent and efficient. Because this change will not be put into practice until next fall, we do not have results to report.

**Changes to the Program’s supporting infrastructure**
Twelve significant changes to the program’s supporting infrastructure have occurred since the last review. Each is discussed below.

*Creation of the Head Advisor position.* When the new School of CBEE was given administrative responsibility for the Chemical Engineering, Bioengineering, and Environmental Engineering programs, there was a need to make the advising systems consistent across the three programs. A Head Advisor position was created and filled in Fall 2005. The Head Advisor has responsibility for managing all advising operations, professional school admits, graduation audits, and the summer student admission program (START). The Head Advisor also manages all advising files and documentation and meets with students on a one-on-one basis as necessary.

- Assessment source leading to and rationale behind the change.
  Prior to formation of our new School, each of the three programs mentioned above operated more or less independently in regard to their advising system. The advising system used for the BIOE program was very good; assessment of advising routinely indicated students were well served and satisfied with their experience. However, when the three programs combined under the same administrative structure, it was necessary to formalize a consistent
system among the three, and given the volume of students now served within the School structure, hiring of a Head Advisor made a lot of sense. Also, a need for more consistent, personal advising, and better transfer of information (e.g., when to apply for a graduation audit) were mentioned in the 2005-06 senior exit interview. Note that this interview was conducted with students from all three programs, so it is difficult to tie directly to concerns expressed by bioengineering students. Separate senior exit interviews were held in subsequent years for this reason.

- PEOs and POs impacted, and results of implementing the change.
  Academic advising has a significant impact on a student’s academic success and subsequent career trajectory. In this way, albeit indirect, all PEOs and POs are impacted by the filling of this new position. Because the Head Advisor is primarily engaged with advising issues, she is very accessible throughout the year to students in need of guidance. She is also able to stay aware of University- and College-level changes in academic procedures, and pass this knowledge on to academic faculty and students alike. From a faculty perspective, the addition of this position has been a great success. While data recorded (through the advising surveys administered after this position was put in place) do not show significant changes in the level of student satisfaction with regard to the advising system, this is most likely due to the high level of satisfaction prior to the creation of the position.

Creation of Internship Coordinator position. In January 2007, the School employed an Internship Coordinator. This person promotes meaningful summer work experiences for students in the School. This is in line with one of the key visions of the College of Engineering which is to produce engineering students who are immediately ready for professional practice upon graduation. Internships also allow students to “preview” professional life, and this often helps them to distinguish among areas of interest within bioengineering.

- Assessment source leading to and rationale behind the change.
  Multiple comments originating from alumni surveys, the 2005-2006 advising survey, and the 2005-2006 senior exit interview identified a need for better guidance relevant to securing internship and jobs. A comment from a respondent to the advising survey suggested that a bulletin board be displayed for presentation of materials relevant to internships.

- PEOs and POs impacted, and results of implementing the change.
  Gaining internship experience has a significant impact on a student’s career trajectory. In this way, albeit indirect, all PEOs are impacted by the filling of this new position. Because the Internship Coordinator is primarily engaged with internship creation and placement, she is very accessible throughout the year to students in need of guidance. Among her most visible efforts, she has constructed a web-based listing of internship and permanent job opportunities, posting positions that she sees advertised in addition to internships about which she has been in contact with the hiring companies. She created and maintains a mailing list of students interested in receiving internship information. Whenever there is new information on the web page she sends a quick e-mail to the list. This has been an effective way to communicate with the students. Finally, she has been very involved in organizing and promoting the Oregon Bioscience Internship and Career Fair (described section 1.3).
From a faculty perspective, the addition of this position has been a great success, and through informal conversations with students, we believe they are satisfied as well. The number of internships bioengineering students secured has nearly doubled since creation of this position. During the summer of 2008, 21% of first-year students, 39% of second-year students, 44% of third-year students and 31% of fourth- and fifth-year students participated in an internship. There have not been any comments, positive or negative, associated with any of our formal assessment instruments, but we have not specifically included questions relevant to this position. Clearly, inclusion of questions relevant to this position would be positive.

**Hiring of a new instructor.** Part of the funding increase CBEE will receive during AY 2007-08 will be used to hire an instructor to assist with the lower division courses with high enrollment (specifically, BIOE 102, 211, 212, and 213).

- Assessment source leading to and rationale behind the change.
  The need for additional teaching support for lower-division courses with high enrollment came from the instructors of these courses, through informal conversations and documented on course summaries. As enrollment numbers increased due to the program merger, the classroom environment changed from a relatively small, highly interactive setting, to a large lecture type setting. Because the lower-division courses are so vital in providing students with essential tools and knowledge needed for success later in the curriculum, it is imperative to do all we can to counteract the negative impacts of high enrollments.

- PEOs and POs impacted, and results of implementing the change.
  This action will primarily impact the development of students’ abilities to apply knowledge of math, science and engineering to solve problems, as well as to formulate and solve engineering problems. However, the lower-division courses provide a cornerstone upon which higher-level coursework stands, so one could potentially link this action to the improvement of student achievement across all POs and PEOs. Because this change will not be put into practice until next academic year, we do not have results to report.

**Replacement of the Linus Pauling Engineer.** The Linus Pauling Engineer position was created in 1998 by an endowment from Peter and Rosalie Johnson. This person is responsible for delivery of the senior laboratory sequence (BIOE 414-415, and CHE 416), a critical set of courses used to transition students from academia to industry and graduate studies. Specifically, the senior laboratory experience engages students in hands-on process operations and control, in data recording and analysis, design of experiments, work in teams, report writing and presentations, and leadership. The Linus Pauling Engineer is required to have extensive industrial experience coupled with a commitment to outstanding teaching; a Ph.D. is desired, but not required. The School selected Dr. Phil Harding to serve as the Linus Pauling Engineer, beginning in the fall of 2007. Dr. Harding came from Hewlett Packard, Corvallis campus.

- Assessment source leading to and rationale behind the change.
  There was no assessment source leading to this action. By design, the Linus Pauling Engineer is filled for a five year period with the potential for renewal.
• PEOs and POs impacted, and results of implementing the change.
The courses Dr. Harding teaches (BIOE 414 and 415, and CHE 416) are important to
students’ professional development, and formally link to nine Program Outcomes (Table 3-1)
for assessment purposes. In turn, these Program Outcomes link to all five Program
Objectives. While Dr. Harding’s appointment is relatively new, he has already made a
significant contribution toward students’ professional development and overall experience in
the program. Most visible among his contributions are the overall development of laboratory
space, including the organization of laboratory equipment into an inventory available
specifically for seniors. He has also improved the feedback cycle for student writing, and
developed and deployed "Pre-lab Assignments" to improve preparation, learning, and lab use
efficiency. Finally, he improved interaction with local industries in regard to senior project
mentoring and assessment. In particular, of the 10 projects carried out in CHE 416, a
financial or supplies "sponsorship" came from 5 companies, with 2 of these projects also
involving an onsite project interaction with practicing engineers. Dr. Harding expects to
expand the latter type of interaction with companies (with onsite project interaction) next
year.

Replacement of a faculty member. A faculty member hired to contribute to the delivery of the
bioengineering program was terminated. He was replaced with Dr. Adam Higgins, who joined
the School in January 2008. Dr. Higgins has expertise in the areas of cell and tissue preservation
technologies (cryopreservation, freeze drying, desiccation, hypothermic storage); cell-based
devices such as biosensors; and applications of microscale fabrication technologies in biology
and medicine, e.g., bio-MEMS.

• Assessment source leading to and rationale behind the change.
There was no assessment source leading to this action. The administration simply allowed the
filling of a vacated position.

• PEOs and POs impacted, and results of implementing the change.
The courses Dr. Higgins teaches or will teach during the upcoming year (BIOE 212, BIOE
340, and BIOE 459) are important to developing students’ abilities to apply knowledge of
math, science and engineering to solve problems, as well as to formulate and solve
engineering problems. Perhaps more importantly is his contribution toward student
achievement along the program specific outcomes that specifically call for the integration of
biology to solve problems. The courses noted above formally link to six Program Outcomes
(Table 3-1) for assessment purposes. In turn, these Program Outcomes link to four of the
five Program Objectives, with most significant overlap along Program Objective 2,
“Graduates will be able to solve problems at the interface of engineering and biology.” While
Dr. Higgins’ appointment is relatively new, he has already made a significant contribution
toward students’ professional development, having taught a well-received bioengineering
selection course last spring (Cell Engineering), and assuming the faculty advisor position to
the student club (Society for Biological Engineers). In regard to his research, he has one
graduate student engaged in a project, and is currently mentoring 3 undergraduates and a
high-school student on projects in his lab.
**Creation of Assistant School Head position.** In the fall of 2006, Assistant School Heads were created as part-time positions to assume management of internal academic issues, including oversight of the specific curriculum, identification of courses to be offered each year, recommendation of faculty workloads, determination of required GTA support, identification of desired new courses, documentation of ABET assessments and incremental improvement, and specification of graduation requirements for their respective programs. An Assistant School Head was appointed for each of the three ABET-accredited programs (Michelle Bothwell, Bioengineering; Keith Levien, Chemical Engineering; and Mark Dolan, Environmental Engineering).

- **Assessment source leading to and rationale behind the change.**
  There is no assessment source that led to this action; rather reorganization of program management produced a need for additional administrative support. Specifically, under the organizational structure for the new School, the responsibilities of the School Head were expanded to include greater external responsibilities including strategic research planning, technology transfer and commercialization, and fund raising. Assistant School Heads were created as part-time positions to assume management of the internal academic issues.

- **PEOs and POs impacted, and results of implementing the change.**
  This change in administrative structure will not directly impact student achievement along any PEO or PO. However, more attention is now focused on refining and implementing the processes leading to continuous program improvement, making the system more efficient and more effective.

**Diversity training for faculty and staff.** During the 2006 fall retreat, faculty and staff spent one half of a day discussing issues of difference, power and privilege and how these social phenomena play out in engineering education and practice. Topics covered included the historical roots of social hierarchy and injustice, the definition and examples of privilege, educational climate for marginalized groups, and how unconscious bias impacts faculty search and interviewing processes, among others.

- **Assessment source leading to and rationale behind the change.**
  The 2005-06 advising survey stated OSU’s policy supporting creation of an inclusive environment and referred to the associated non-discrimination policy. Following, students were asked to rate adherence to this policy. Over 97% of the bioengineering respondents scored this question with a 5 (on a 5 point Likert scale), indicating the highest level of adherence. However, through informal conversations with students, it is apparent that discriminatory events do occur, and that some students feel the environment is not as inclusive as it could be. A goal of the University, the College of Engineering and CBEE is to increase diversity of the student body. The engineering profession remains dominated by white males, and the climate in engineering education and practice continues to be “chilly” for many outside of the dominant paradigm. It is important, therefore, that faculty and staff engage issues surrounding oppression and privilege in order to change our professional culture so that marginalized groups can be successful because of what they bring, rather than in spite of it.
• PEOs and POs impacted, and results of implementing the change.
Educating people about issues of privilege has the potential to genuinely bring about a shift in the engineering professional culture such that all participants feel welcomed and valued. If such a shift did occur, we would expect achievement along all PEOs and POs to increase. A safe, welcoming environment promotes learning, as does one with diverse perspectives represented. While no formal assessment has been completed to measure the impact of the training, there seems to be no change in the number of informal discriminatory incidents reported. However, talking about such issues is vitally important. Raising awareness that change is needed is a good first step.

Course values statement drafted. During AY 2006-07 a course values statement was drafted for inclusion on syllabi of courses delivered through CBEE. The statement reads:

_I am dedicated to establishing an inclusive learning environment that values all students’ experiences. Therefore, disrespectful and demeaning statements, attitudes, and behaviors based on age, ability, color/ethnicity/race, gender identity/expression, immigration status, marital/parental status, military/veteran’s status, national origin, political affiliation, religious/spiritual beliefs, sex, sexual orientation, socioeconomic status will not be tolerated._

• Assessment source leading to and rationale behind the change.
The assessment source and rationale for this change is the same as that described above for the diversity training. It is important that faculty directly state our School’s values with regard to inclusion. It provides a clear set of expectations that will enhance our community.

• PEOs and POs impacted, and results of implementing the change.
If classrooms are indeed inclusive such that all participants feel welcomed and valued, we would expect achievement along all PEOs and POs to increase. A safe, welcoming environment promotes learning, as does one with diverse perspectives represented. While no formal assessment has been completed, it is unlikely that adding such a statement to syllabi would have a dramatic impact. However, clearly stating our School’s values with regard inclusion is vitally important.

Formal approval of School structure. The School of Chemical, Biological and Environmental Engineering was created in a college-wide move to consolidate departments. In that move, Electrical and Computer Engineering and Computer Science were consolidated into Electrical Engineering and Computer Science (EECS), Mechanical Engineering and Industrial and Manufacturing Engineering were combined into Mechanical, Industrial and Manufacturing Engineering (MIME), and Chemical Engineering, Bioengineering and Environmental Engineering were merged into Chemical, Biological and Environmental Engineering (CBEE). EECS was approved in 2005 and MIME and CCBE were approved in 2007.

• Assessment source leading to and rationale behind the change.
There is no assessment source that led to this action; rather it was driven by the benefits that would be gained by reorganization. Specifically, the consolidation resulted in a substantial reduction of administration costs, greater opportunities for multi-disciplinary research, more comprehensive advising, and consolidation of course offering.
• PEOs and POs impacted, and results of implementing the change.
This change in administrative structure will not directly impact student achievement along any PEO or PO. However, this structure has allowed for the creation of positions that support student learning and achievement (Head Advisor and the Internship Coordinator, in particular). Results of adding these positions are discussed above. In addition, the consolidation of the programs has increased faculty resources such that the core course offerings could be expanded. This is described later in this section.

School’s Web page revision. During the past two years, the School’s web pages have been revised to reflect changes in the administrative structure and to conform to the general format used by units associated with the College of Engineering. The bioengineering program pages have been updated routinely such that the PEOs and POs remain current, as well as the information regarding our Industrial Advisory Board.

• Assessment source leading to and rationale behind the change.
There is no assessment source that led to this action; rather it was driven by the desire to accurately represent our School’s activities.

• PEOs and POs impacted, and results of implementing the change.
This change in web page content and structure does not directly impact student achievement along any PEO or PO. However, it does ensure that students and others have accurate information about department activities, including academic programs.

Closure of open gated areas in Gleeson Hall. The old pilot plant unit in Gleeson Hall, including the open grated areas on the first, second and third floors was closed for further use. These areas had served as a student lounge on the first floor and laboratory areas on the second and third floor. These areas represent a loss of about 2000 ft². Remodeling of these areas to meet fire code was determined to be prohibitively expensive. For the short term, the student lounge was moved to the Gleeson entrance, laboratories on the 2nd floor were consolidated, and laboratories on the 3rd floor were moved to Graf Hall.

• Assessment source leading to and rationale behind the change.
There is no assessment source that led to this action; rather it was driven by an order from the State Fire Marshall.

• PEOs and POs impacted, and results of implementing the change.
This change in space allocation should not directly impact student achievement along any PEO or PO, given that other areas have been identified to replace the space lost in Gleeson Hall. However, it should be noted that during the 2007-08 senior exit interview, students indicated their dissatisfaction with the move of the student lounge to the Gleeson entrance. Given space and financial constraints, this issue cannot be immediately addressed.

College’s commitment to remodeling. The Engineering Technology Industry Council (ETIC) is a program managed by the Governor’s Office and the State Board of Higher Education by which targeted funding is provided to the College of Engineering at Oregon State University and several other colleges and programs in the Oregon State University System. Started in 2000,
funding from ETIC has grown to where it now comprises about 40% of CBEE’s budget. The money is used for professors’ salaries and for equipment and facilities improvement. Using ETIC funding, the COE committed to remodel space in Owen and Graf Halls to compensate for the loss of space in Gleeson Hall. Additional instructional space was added by remodeling Owen 109 for the senior laboratory classes, Graf 208 for BIOE 101 and 102, and Graf 210 for ChE 333. Laboratory space was added in Owen 406 and 411 and in Graf 308 and 309.

- Assessment source leading to and rationale behind the change.
  There is no assessment source that led to this action, rather it was driven by a need to replace the space lost in Gleeson Hall due to forced closure by the State Fire Marshall.

- PEOs and POs impacted, and results of implementing the change.
  This change in space allocation should not directly impact student achievement along any PEO or PO, given that the remodeled areas described here are simply replacing comparable areas lost in Gleeson Hall.

Changes to the curriculum
Many significant changes to the program’s curriculum have occurred since the last review (some of which are described in section B-6). These changes can be placed into seven broad categories, e.g., changes made to the bioscience requirements, enhancements made to design instruction, etc. Each of these broad, categorical changes will be discussed below.

Leverage resources to expand course offerings. Following the merger, the number of faculty available to teach core courses, taken by students across all three programs, increased. This allowed for the expansion of the School’s course offerings. In particular, material and energy balances were previously taught in a single, 4 credit hour course. The material is now delivered through a required, 2 course sequence. “Introduction to Statistics for Engineers” (ST 314) was replaced by a required, 4 credit hour course entitled “BIOE 213 Process Analysis,” taught by a CBEE faculty member. This course covers probability and statistics and contains a laboratory component involving design of experiments, data analysis and process simulation. Finally, fluid mechanics and mass transfer were traditionally offered through CBEE, but bioengineering students used to be instructed in heat transfer through a general engineering course (taught through a mechanical engineering framework). Currently, all three topics are taught through CBEE, in a 3-course (11 credit hours) transport phenomena sequence that includes a laboratory component. These changes were introduced during AY 2006-07.

- Assessment source leading to and rationale behind the change.
  Course summaries identified the biggest impediment to students gaining mastery of material and energy balances as being the limited amount of time (10 weeks) in which to engage a lot of concepts. At most schools, mass and energy balances are taught in either two quarters (20 weeks), or 1 semester (15 weeks). The 2005-06 program-level assessment of Program Outcomes “a” and “e” also recommend delivering this content over two quarters. Recall from previous sections relevant to achievement along each PEO and PO, our alumni identified deficiencies in their abilities to solve engineering problems (“e”). The ability to effectively engage material and energy balances is crucial for the attainment of this outcome. In addition, enhancing delivery of this content should contribute to addressing the deficiency
noted in achievement of the PEO relevant to graduate work-readiness. Recall that achievement along this PEO was ranked the lowest of the five by alumni and employers.

Participants in the 2005-06 senior exit interview noted that their experience in ST 314 was not satisfying, and they recommended that a statistics course be taught by a CBEE faculty member so that the content could be delivered using the context of their discipline. Participants in the 2007-08 senior exit interview noted lack of a thorough understanding of statistical principles, especially the application of ANOVA. Participants in the latter interview were from the last class to take ST 314. In addition, a respondent to the Alumni Survey specifically identified a need for a better understanding of statistics. Regarding achievement along each PEO and PO, our alumni identified a deficiency in their ability to use engineering tools (“k”). The new Process Analysis course provides an improved opportunity for students to engage techniques associated with data analysis and experimentation through the use of appropriate software (Excel, MATLAB, and StatGraphics). This exposure is beneficial toward the attainment of Program Outcome “k.” In addition, enhancing delivery of this content should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness. Recall that achievement along this PEO was ranked the lowest of the five by alumni and employers.

BIOE 213 Process Analysis mainly supports Program Outcomes “b” and “k,” each of which is linked to attainment of the work-readiness objective.

Several assessment sources indicated that instruction of heat transfer using a mechanical engineering framework was not optimal. The 2005-06 program-level assessment of Program Outcome “a” recommended that process heat transfer concepts be incorporated into the transport series. However, this was not feasible when the curriculum included the general engineering heat transfer course, which was not focused on processes, but certainly could be accommodated if the course was taught within our School. Participants in the 2005-06 senior exit interview expressed dissatisfaction with the general heat transfer course (one participant noted, “[The general heat transfer course] was horrible, a waste of time. The material didn’t make any sense until completing mass transfer [which was taught within a process framework].”). In addition, our alumni identified deficiencies in their design ability (“c”), and ability to solve engineering problems (“e”), among other areas. Restructuring the transport series so that a process framework is used throughout and adding a laboratory component should enhance student learning. Concepts presented in these courses are foundational, and directly support the outcomes stated above. Enhancing delivery of this content should also contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness. The three courses in the new transport sequence collectively support Program Outcomes “b,” “c,” and “e,” all three of which are linked to attainment of the work-readiness objective.

- PEOs and POs impacted, and results of implementing the change.
  The objectives and outcomes impacted by these changes, with exception of Program Outcome “a,” were highlighted above as part of the discussion of assessment sources leading to the changes. Students’ abilities to apply math, science and engineering to solve problems are formally assessed in the material and energy balance sequence and in the third course of
the transport sequence. In general, all the courses mentioned here support this outcome, and by enhancing the delivery of the material, student learning should also be enhanced.

The changes are relatively new; students who were in their fourth year of study during AY 2007-08 did complete the new transport series, but they did not benefit by the changes to the material and energy balance delivery or by the new Process Analysis course. And of course, data provided by alumni and employers would not be based on experiences with the new curriculum. Given this, it is hard to provide concrete data that points to improvement along PO and PEO achievement; however, we believe the new course of study is superior and positive results should become apparent within the next few years.

**Bioscience requirements.** Several changes have been made to the curriculum in regard to bioscience coursework. One change involved replacing a two term course sequence entitled “Biomedical Science for Engineers” with two required courses in human anatomy and physiology (Z 331 and Z 333) and a new course delivered through our department, BIOE 340 Biomedical Engineering Principles. A second change involved removing BI 314 Cell and Molecular Biology from the curriculum. The material taught in this course is covered in other courses, although the delivery is not as comprehensive. In particular, cell biology content is taught in the new Biomedical Engineering Principles course, as well as the new Cell Engineering selection course. Molecular biology content has been incorporated into BIOE 457 Bioreactors, and is also a major part of the biochemistry lecture and lab sequences. Finally, students must complete one additional selection course in the biosciences (either an anatomy and physiology laboratory or a microbiology lecture and laboratory course, depending on their career interests).

- Assessment source leading to and rationale behind the change, and PEOs and POs impacted. During the last accreditation review, a concern was raised about the physiology component of the curriculum. While students were required to complete the first course of a “Biomedical Science for Engineers” sequence, this course content focused on molecular-, cell- and tissue-level topics. An elective course on systems physiology was available, but students were not required to enroll. This was evident in the 2005-06 program-level assessment of Program Outcome “I,” where it was recommended that we “provide students with a broader background in systems physiology and couple this content with engineering principles.” This need was also identified by students in the 2005-06 senior exit interview, where participants noted a desire to have more exposure to anatomy and physiology.

There was no assessment source that led to the removal of Cell and Molecular Biology from the curriculum, although we are aware, through informal conversations, that students found the course content to be somewhat redundant with material delivered in the biochemistry sequences. This change was implemented because the Biology Program began enforcing a 15 credit hour general biology prerequisite. Given credit hour limitations, it was impossible for our students to meet this prerequisite. The 2006-07 program-level assessment of Program Outcome “I,” indicates a need to address material “lost” from the curriculum due to this change. In particular, it was recommended that organelle structure and function be taught within the Biomedical Engineering course, and that the new upper-division bioengineering elective course, Cell Engineering, reinforce the application of cell biology to solve problems. This evaluation also indicated that students should be exposed to molecular biology.
techniques in the Bioreactors course, preparing them for the subsequent biochemistry laboratory courses.

The inclusion of a bioscience selection course that includes a laboratory component was prompted by discussions with the University’s Baccalaureate Core Committee. All OSU students must fulfill a biology course requirement prior to graduation, and restrictions on this course include that it be a lower-division, broad spectrum course with a laboratory component. The microbiology course is part of the official list of courses fulfilling this University requirement, but the anatomy and physiology laboratories are not. However, the University made an exception in the case of bioengineering majors, considering that these students would be exposed to what they considered adequate bioscience content beyond the baccalaureate core requirement in this area.

Data from the employers’ survey is relevant to all three changes described above. In particular, data recorded identify that graduates’ knowledge of biosciences could be improved, Program Outcome “l.” This directly correlates with achievement in solving problems at the interface of engineering and biology (PEO 2), the second lowest ranked PEO in regard to achievement, as rated by employers and alumni. Note that all of the changes to bioscience content have been phased in primarily during the past academic year, although some of the changes occurred during the end of AY 2006-07.

- Results of implementing the change.
The objective and outcome impacted by these changes are identified above. The changes are relatively new; students who were in their fourth year of study during AY 2007-08 were caught in the transition. Most did not complete the anatomy and physiology requirements, although they did complete a 5 credit hour version of the Biomedical Engineering Principles course, where physiology content was a major feature. And of course, data provided by alumni and employers would not be based on experiences with the new curriculum. Given this, it is hard to provide concrete data that points to improvement along PO and PEO achievement; however, we believe the new course of study is superior and positive results should become apparent within the next few years.

Enhancement to instruction of design. A couple of changes have been made to the curriculum with regard to design instruction. One change involved the addition of a new 4 credit hour course focused on product design, BIOE 390 Bioengineering Product Design. Our intention in this course is to introduce 3rd year students to the concept of design of devices and products, as opposed to processes. The course will include significant economic analysis content, and content on applying process engineering fundamentals (mass and energy balances, bioreaction kinetics and transport phenomena) to relevant product design. The other major change was increasing the credit hours associated with the senior, capstone, process design course from 3 to 4. These changes will be implemented AY 2008-09.

- Assessment source leading to and rationale behind the change, and PEOs and POs impacted.
The 2008 graduating seniors identified a deficiency in their ability to design (“c”), as did respondents to the alumni survey. During the 2006-07 senior exit interview, participants stated that they wished they had more design experience, specifically citing the lack of...
device design as problematic. Our IAB has identified the lack of product design in the curriculum as a weakness, but also recognized that this is not the focus of the program. A one-quarter capstone design experience is minimal, most engineering programs have a two-quarter design series or even an entire year series. The proposed course will address this deficiency, providing additional design experience. The two design courses together, in combination with the intensive senior laboratory sequence, form a critical set of courses used to transition students from academia to industry and graduate studies. Enhancing delivery of this design content should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness. Recall that achievement along this PEO was ranked the lowest of the five by alumni and employers. The main Program Outcomes BIOE 390 supports are “c,” “p,” and “q,” all three of which are linked to attainment of the work-readiness objective.

In order to accommodate additional design coursework, another engineering science and design course had to be removed from the curriculum, and it was decided to remove ENGR 390 Engineering Economics. This course was deleted because we believe the content of the course could be delivered as well or better in the context of engineering design. In addition, over the years, through informal conversations with students and during senior exit interviews, we have become aware that students are dissatisfied with their experiences in ENGR 390, the general engineering economics course.

• Results of implementing the change.
  Because these changes will not be put into practice until AY 2008-09, we do not have results to report.

Addition of a stand-alone course on regulatory processes. A course in regulation of drugs and medical devices (BIOE 470) was developed and taught for the first time during the 2005-06 academic year. This course is required for all bioengineering majors.

• Assessment source leading to and rationale behind the change, and PEOs and POs impacted.
  The initial recommendation to consider incorporating a course on regulatory processes came from discussion with our IAB. This action was further supported by data recorded through the employer survey, which noted a deficiency in our alumni’s knowledge of regulatory issues (“p”). A respondent of our alumni survey indicated that he or she would have benefited by exposure to regulatory issues, and a respondent to the employer survey provided specific feedback for improving the program, stating “… I recommend more preparation on the global regulatory environment, including FDA’s QSIT and the MDDs Global Harmonization Taskforce.” BIOE 470 provides an essential knowledge base; regulatory issues are an important aspect for most industries where bioengineering students will eventually find employment. In addition to making their transition to the work place easier and faster, the knowledge gained from this course distinguishes them from other candidates when searching for career opportunities. Delivery of this content should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness. Recall that achievement along this PEO was ranked the lowest of the five by alumni and employers. The main Program Outcome BIOE 470 supports is “p,” which is linked to attainment of the work-readiness objective.
• Results of implementing the change.
The only formal assessment results we have obtained regarding this change are measures
documenting graduating seniors’ self-assessment of their abilities to meet Program Outcome
“p.” Figure 3-3 illustrates that graduating seniors from 2006 onward are confident in their
knowledge of regulatory issues, with ratings well above 4.0 in all cases. Since delivering this
class, several of our graduates have secured employment as validation engineers. Other
informal feedback has come from graduates who have indicated that their employers were
impressed with their knowledge of regulatory processes, with this knowledge playing a
critical role in job attainment.

Enhancements to laboratory experiences. Several changes have occurred to the curriculum’s
laboratory experiences since the last accreditation visit. Prior to the visit, the program had labs in
the first and fourth years of study, leaving the second and third years of study without
experiential learning opportunities in the major. As described above, in AY 2006-07, three new
courses were introduced to the program: BIOE 213 Process Analysis, CHE 333 Transport
Phenomena III, and BIOE 340 Biomedical Engineering Principles. The first of these courses has
a significant laboratory component involving design of experiments, data analysis and process
simulation. The second listed is the final course in the transport sequence, and is completely lab-
based, demonstrating transport principles introduced in CHE 331 and CHE 332. The Biomedical
Engineering Principles course has a significant laboratory component, including the analysis of
the heart with EKG, measurement of lung volumes and capacities, measurement of oxygen
extraction by the lungs, analysis of respiratory responses to physiological challenges, and
analysis of the effect of vascularity on skin temperature recovery, among others.

Another shift in experiential learning opportunities took place in the fourth-year of study. In
particular, the laboratory components associated with BIOE 457 Bioreactors and BIOE 462
Biosepartations were replaced with a required 2-course, 6 credit hour, bioengineering laboratory
sequence, covering common bioengineering unit operations and processes (BIOE 414 and 415).
The content of the new senior laboratory courses is described in more detail in sections 5.1 and
5.3 of this report. While a third senior laboratory course (CHE 416) is not required, it is available
and can be used by bioengineering students to fulfill engineering elective requirements. This
course assigns students to project teams, and these teams choose various sponsored projects on
which to work. Last year, of the 10 projects carried out in CHE 416, a financial or supplies
"sponsorship" came from 5 companies, with 2 of these projects also involving an onsite project
interaction with practicing engineers. Dr. Harding, the instructor of the course, expects to
expand the latter type of interaction with companies (with onsite project interaction) next year.

• Assessment source leading to and rationale behind the change, and PEOs and POs impacted.
In the 2005-06 program-level assessment of Program Outcome “b,” it was recommended that
more experiential learning opportunities be incorporated in the second and third years of
study. And, the 2005-06 program-level assessment of Program Outcome “n,” suggested that
a physiology laboratory be incorporated into the curriculum.

The 2006-07 program-level assessment of Program Outcome “n,” recommended that an
“open-ended project that includes design, performance, analysis and interpretation” be added
to the curriculum. This sort of recommendation came from participants of the 2006-07 senior exit interview as well, identifying a need for “real-world” experience. Similar feedback was provided by a respondent of the alumni survey, who wrote there was a need for “actual, realistic projects that require lab experience in collaboration with industry or clinical practice.” Inclusion of the senior laboratory sequence addresses these needs.

Survey data recorded for graduating seniors, alumni and employers of our alumni show no deficiencies in achievement levels along Program Outcomes “b” and “n.” However, enhancing experiential learning opportunities has been shown, through educational research, to enhance learning, and increase material retention. Creation of laboratory-based learning opportunities should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness, as Program Outcome “b” is linked to attainment of the work-readiness objective. Further, the achievement of the PEO addressing the ability to solve problems at the interface of engineering and biology should also rise, as Program Outcome “n” is linked to attainment of this objective.

- Results of implementing the change.
The changes are relatively new; students who were in their fourth year of study during AY 2007-08 did complete the new transport series, and an expanded version of the Biomedical Engineering Principles course, but they did not benefit by the new process analysis course. Because this cohort completed some of the new coursework during its first offering, content and delivery were not optimal. And of course, data provided by alumni and employers would not be based on experiences with the new curriculum. Given all of this, it is hard to provide concrete data that points to improvement along PO and PEO achievement; however, we believe the new course of study is superior and positive results should become apparent within the next few years.

Enhancements to experiences using Matlab. Instructors of several key bioengineering courses have made a significant effort to incorporate the use of Matlab as a tool to solve engineering problems. Specifically, in AY 2005-06, problems which involved the use of Matlab were introduced into the required course, BIOE 457 Bioreactors, as well as the bioengineering selection course, BIOE 451 Biomaterials and Biointerfaces. In AY 2007-08, problems which involved the use of Matlab were introduced as essential elements of the required course, BIOE 340 Biomedical Engineering Principles, as well as the bioengineering selection course, BIOE 459 Cell Engineering.

- Assessment source leading to and rationale behind the change, and PEOs and POs impacted.
There has been considerable feedback that specifically asked that the number of opportunities to work within the Matlab environment be increased. In particular, participants of the 2006 and 2008 senior exit interviews stated that they wished they had been able to use Matlab on a more consistent basis. Many were introduced to Matlab in BIOE 102, but did not work with the software again until their fourth year of study. The 2005-06 program-level assessment of Program Outcome “m,” stated that “students ought to be made more familiar with tools available for matrix manipulation and mathematical modeling in general.” And the 2006-07 program-level assessment of Program Outcome “k” recommended integrating Matlab into third year courses. This action was further supported by data recorded through the alumni
survey, which noted a deficiency in our alumni’s ability to use the techniques, skills and modern engineering tools necessary for engineering practice (“k”). Three respondents to this survey indicated that they would have benefited by more exposure to the Matlab environment and/or more experience with modeling and programming. Creation of more opportunities to work with Matlab should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness, as Program Outcome “k” is linked to attainment of the work-readiness objective.

- Results of implementing the change.
  The changes are relatively new; some of the students who were in their fourth year of study during AY 2007-08 only engaged the Matlab environment during their first year of study and then again in one course during their last year of study. Given this, it is hard to provide concrete data that points to improvement along PO and PEO achievement; however, we believe the new opportunities in this area should have documentable, positive results within a few years.

*Increase delivery of content relevant to business forces that impact design.* Delivery of content relevant to business forces that impact design and decision making, such as entrepreneurship, financial constraints, profitability, and intellectual property and patent issues (Program Outcome “q”), is continually being enhanced. In particular, during AY 2006-07, an entrepreneur presented a lecture on business case analysis, in the capstone design, and during AY 2007-08, the same course hosted a university technology transfer officer who discussed issues relevant to intellectual property and the patent application system. During this same year, as part of the capstone design course, students were required to read two articles related to the importance of entrepreneurship within the biotechnology industry and another related to intellectual property. A new required section to the overall design report (Market Analysis) was added for the first time during this year as well.

Action constituting an important improvement for the 2008-09 academic year to the bioengineering selection course, BIOE 451 Biomaterials and BioInterfaces, is the incorporation of a multi-week project that will require students to use their increasing awareness of the kinds of business forces that impact design and decision making. The plan is to construct a project around research, development and commercialization phases of an antimicrobial coating for central venous catheters.

- Assessment source leading to and rationale behind the change, and PEOs and POs impacted.
  Most of the assessment instruments used to record data to be used for program improvement indicate that the bioengineering program does not do an adequate job in preparing students to successfully meet Program Outcome “q.” In particular, both the 2005-06 and 2006-07 program-level assessment of Program Outcome “q” indicate that content around and assessment measures for attainment of this learning outcome be enhanced. A respondent to the 2008 senior survey, and a respondent to the alumni survey, indicated that the program could be improved with better coverage of business forces that impact design and decision making. Finally, graduates from 2006-2008 and alumni all rated their awareness of business forces below the level set for adequate achievement. Employers rating the abilities of our alumni showed similar results. Clearly, this is the biggest opportunity for improvement to
the bioengineering program. Better coverage of business forces that impact design and decision making should contribute to addressing the deficiency noted in achievement of the PEO relevant to graduate work-readiness, as Program Outcome “q” is linked to attainment of the work-readiness objective.

- Results of implementing the change.
The changes to date around this area have been relatively small, but are important steps to addressing the documented deficiency. Planned changes for next year will enhance the students’ learning experiences around this content. In any event, the Bioengineering Program faculty will discuss this particular deficiency in detail during our upcoming retreat, and formulate a solid plan that will ensure that the deficiency is remedied.